



Modern Geo-ecological Conditions and Terrain Transformation of Tbilisi (Georgia)

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Abstract: Throughout the course of history (especially since the late 1900s) the development of Tbilisi as the capital city, demanded a high level of urbanization. This ever-increasing demand was met with the erection of new dwellings, social hubs (e.g. parks) and infrastructural projects. Riverbeds were diverted in order to clear way for new transportation roots, hillsides and slopes made into large terraces for construction of tall buildings, roads and junctions were also put in place as well as new sufficient railroad tracks going around the city rather than directly through it. To supply the city with fresh water new vast reservoirs were built. Such anthropogenic activity is still evident in Tbilisi. Towns represent complex artificial engineering structures of social-economic nature. The interaction between towns and their surrounding shares a perpetually evolving character. The urbanization and utilization of vast territories for energy resources gives an impetus to an environmental shift of a global scale. Urbanized localities are, therefore, the highest forms of human habitation. Urbanization as a notion is considered to be a factor in the improvement social advancement. However, there are certain contradictions as some forms of such advancement may in fact bring more harm than benefit to the society. The rapid rise in the population of an urbanized locality ultimately results in the formation of uncontrollable, problematic, and often illegal slums and shantytowns. A wide-ranging, complex study of the surrounding environments of the town, however, is an essential component to regulating such processes. Such studies can act as a foundation for effective geo-ecological development and for planning priorities and strategies of further work. Hazardous exo-dynamic processes (Landslides, debrisflow/mudflows, avalanches, riverbed erosions etc) as well as the rapid growth of the human population has placed Tbilisi into the category of highly dangerous territories, as any natural catastrophe that may occur within the limits of the city will result in excessive economic and humanitarian losses. The study of geo-ecological and landscape transformation of Tbilisi is, thus, of both academic and practical use.

Keywords: Tbilisi, Terrain Transformation, Relief, Hazardous Processes

1. Introduction

Many facts influenced on the formation of cities in present condition. Urban area constantly was changing. Currently it undergoes transformation and reconstruction of urban planning structure followed by the transformation of relief, changes of all basic parameters and elements of urban planning system.

Problems of urbanization development are quite hard and urgent on all levels of its structure, especially in Tbilisi. Development of cities stipulated construction activities on the territories and formation of urban area (especially from

the second half of the 20th century) expressed in the development of new residential and public areas and infrastructure projects. Riverbeds are changed for the development of transport infrastructure; slopes are cut off or leveled for housing development and provided intervention in hydrologic network and others.

Urban area constantly used to be changed and even today, it undergoes changes. The problem became more topical in the beginning of the 21st century. For the last period, it is 2.5 times increased. Pressing increased by the activity of humans became evident, lands intended for the construction time by time becomes more scarce and expensive resource and construction on the risk areas are included on the agenda that

will be followed by geo-ecologic disasters. Because of great anthropogenic impacts, 2/5 of Tbilisi's territory is developed but the rest are transformed. Tbilisi also undergoes transformation and reconstruction of urban planning structure. Urban development includes changes of all main parameters and elements of urban planning system: transformation of suburbs to urban environment, construction of main roads, decrease of capital's green zone, lack of recreation areas, quick rate of urbanization, quick rate of integration of suburbs to city and many others, problems of Tbilisi urban development on all levels of its structure are quite urgent.

Tbilisi is situated on complicated geological and geomorphologic areas, with quite hard hydrogeology, and high population especially in geologically complicated areas. Relief of territory subject to the study in the regions is extremely transformed due to anthropogenic impact taking place for many centuries and gradually becomes intensified. Together with the increase of urbanization, new territories are involved in this process. It is stipulated by complicated morphology of initial relief, low physical and mechanical features of host rocks and extremely limited conditions for the urban development. Lack of consideration of complex geo-ecologic conditions and construction on the territories without any appropriate evaluation led us to very negative results. Cut off of slopes with great inclinations, filling of ravines and closed depressions with domestic material and technologic soil for construction and communication buildings caused quite a complicated geo-ecologic condition of city. Together with the previously mentioned, future scenes for the urban development would be very interesting and for this purpose are formed various models. Exactly this relates to the news of this research. All main factors (relief, transportation lines, demography, changes of the types of plot usage) influencing development of urban settlement will be reviewed during the research process.

At present, under the conditions of increased demand on constructions, the territory of Tbilisi city is being developed under the most complex geological conditions, which is frequently accompanied by widespread occurrence and activation of natural hazards, such as landslide-gravitational events, debrisflow/mudflows, floods, flashfloods, triggered by heavy rainfall, also extreme complications of geo-ecological situation [1].

The study and sustainability of the surrounding environment of Tbilisi as well as careful planning of its developments considering the growth of the city is essential to the functioning of the capital city. The study of the sustainability of the landscape of Tbilisi is of both general-academic and practical importance. The occurring problems require conducting a swift study and in order to reach solutions to stabilise the situation. Although the rapid urbanization in Europe started in the mid-nineteenth century, the study of it dates back to only the 1900s. When discussing academic literature regarding geo-ecology it is worthwhile to mention a curious tendency – as the number of such publications doubled after the period of 1970-90s. The

interest towards conducting scientific studies about Tbilisi however dates back to the XIX century.

Scientific institutes and governmental organisations operate across a variety of countries dedicated to the study of geo-ecology of prominent urbanised areas. Georgia is not an exception, as the sustainability of towns as well as the study of geo-ecology of populated areas is somewhat momentous.

A comprehensive assessment of the surroundings of towns is a crucial stage in regulating geo-ecological developments, whilst simultaneously creating foundations for determining future strategies and priorities.

2. Study Area

The field works will take place in Eastern Georgia in the eastern part of the Kartli plain. In terms of Geomorphology the city of Tbilisi along with its immediate surroundings is considered as difficult terrain being situated on the eastern end of the Achara-Trialeti mountain range (Figure 1).

Capital city of Georgia-Tbilisi is an important political, economic and cultural center. Tbilisi has been mentioned as a city since 458 AD. The longitude of study area is 44° 47' E and the latitude 41° 43' N. The city is located along the river Mtkvari for 33km and spans an area of 372 km sq. Tbilisi has a mined climate. The summers tend to be relatively hotter and winters colder. Tbilisi is located in a rather difficult region in terms of terrain. This has in turn determined the nature of the development of the city. Due to its geological composition and climate as well as the exo-dynamic processes like urbanization the territory represents a structural basin with an uneven surface which is bisected by the Mtkvari river [2]. The first urban growth of Tbilisi began back in the XIX century after Georgia became subject to the Russian Tsar. The city become the seat of the new governor and viceroy therefore, new European-style buildings were constructed around the settlement. Road were constructed. Railways were also built to link up Tbilisi to the rest of the empire including towns in Caucasus like; Batumi, Poti, Baku, Erevan, etc. So in the 1850s Tbilisi was reinvented as an important political, cultural, commercial and administrative center in southern Caucasus. The city also saw major growth under the Soviet rule. The second wave of urbanization erupted in mid XX century, with an influx of laborers and the emergence of factories and other similar facilities. By the year of 1990 17.4% of the surface of Tbilisi was an industrial zone.

Also Tbilisi and its surroundings are to a certain extent geologically unsustainable having gone through both early and modern erosive processes. The field works will take place along the central part of the Mtkvari river depression, ranging from the Saguramo-Ialno morphostructure to the north, the Mtkvari river to the south-west and the Iori river gorge to the east. Tectonic activity is one of the main factors in the formation of prominent morphological structures of this region. Additional effects are created by anthropogenic landscape transformations as well as various forms of farming and agriculture, resulting in catastrophic consequences for future development of Tbilisi.



Figure 1. Study Area.

3. Main Body

As time and practice have shown, it is crucial to the study of urban environments to consider and implement methods and analytical foundations, which more or less cover the entire surroundings of the city including a detailed description of specific variables and processes, especially in terms of climate change.

Studies show that in the past most of Tbilisi's surface was covered with forests. Currently green territories in Tbilisi per capita occupy an area ten times smaller than that of European standards. Presently, the initial nature of the surroundings of Tbilisi has been disturbed and morphed into anthropogenic landscapes, due to prolonged industrial activity of various sorts.

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The analysis of the dynamic state of specific landscapes plays a pivotal role in determining and enhancing the parametric sustainability and the development of social systems. For appropriate management of facilities it is necessary to acquire exact data, allowing a us to better position new settlements as well as cultural areas. In the mean time, the rise in the demand of social-economic nature places further strain on the environment. Currently, environments in particular areas of Tbilisi suffer a great deal of anthropogenic pressing. Such a poor state and the potential negative trends of development of the environment in Tbilisi are often caused by negligence or unsustainable use of resources through human activity. Ultimately this leads to anthropogenic transformations within the landscape of the proposed region.

The main factors in the formation of the landscape of Tbilisi basin are; the history of the development of the landscape, its morpho-graphy, morpho-metry, modern exo-dynamic processes as well as the anthropogenic transformations of the landscape. The latter was the result of

the prolonged urbanization process, which lasted centuries as the city evolved. Rivers were diverted into underground channels and paved over with roads, whilst the mountain slopes were terraced in order to make way for constructions. Among many other anthropogenic changes was also the formation of the Tbilisi reservoir.

The formation of the landscape of Tbilisi in its present form began in the early Pliocene period. Due to its erosive nature river Mtkvari being the main hydrographical artery of the region played a pivotal role in this process. Excluding the Kvashveti and Samgori alluvial valleys, there are four (Makhata, Lotkin, Gori and Vake-Avlabari & Chughureti) terraces in Tbilisi all situated around the river Mtkvari. All four cyclic terraces acting as the foundation for the development of Tbilisi's Landscape. In terms of geological composition the landscape of the surroundings of Tbilisi is characterised by tectonic movements as well as river erosions and accumulations.

Around Tbilisi (and within the actual city) one would often notice anthropogenic landscapes mainly represented by artificially created terraces. Obviously, such landscapes were created out of necessity as the topographic surroundings of Tbilisi are heavily partitioned into gorges and the mountain slopes are adjacent to urbanised areas, not allowing the city to grow as it would naturally. Thus, the local population has long used the practice of terracing the slopes. Such terraces are observed on both sides of Tbilisi on severely skewed slopes of the Mtatsminda, Makhata, Dzedzva, Keeni and Lotkin mountain ranges etc. However there were other reasons to why there terraces were created; it was necessary to create artificial terraces to deter the advance of erosive processes. Such processes occur quite often in Tbilisi, due to the nature of the local landscape and climate. For example, during the heavy rainfall season slopes without a strong floral cover come under effects of intensive erosion. In this sense terraces were ultimately the perfect solution for this occurrence.

In the past several springs cut through what is now populated areas of Tbilisi. However, not only did they use to separate the urbanised areas, but they also spread dysentery. During heavy rainfall season they would overflow causing

havoc on streets and squares of the town, often even - casualties among the population. Currently these springs have been diverted into underground channels and paved over with road of tarmac or parks.

There were, indeed, Orbeliani Islands on the river Mtkvari (later known as the Madatov Islands) as well as the Ortachala Islands etc. As a part of the general city planning program the river was diverted into a single stream attaching these islands onto mainland Tbilisi.

4. Methodology

The research is based on a complex physical-geographic, field study, benchmark mapping, semi-stationary observation methods and GIS analyses. To establish landscape situations and their dynamic, remote sensing materials (air and space methods) of various years were deciphered in order to provide qualitative analysis of natural objects and processes within a reasonable time. The research draws on textual and cartographical resources, topographical maps of Tbilisi. A comparative analysis of old and new sets of data were conducted based on the deciphered information from aerial and satellite imagery. The research methods for this article include appropriate literature, data from proposed and completed projects, visual observations as well as an analysis based on scientific research, which takes into account historical, statistical and cartographic information. The method of systemic research was also employed in this article, regarding the geo-ecological state and landscape transformation of the suburbs of Tbilisi.

5. Natural Hazards

Protection of the population of Georgia against the Natural hazards, land preservation and safe operation of infrastructure objects has become a most important social-economic, demographic, political and ecological problem quite a long time ago [3]. Hazardous Exodynamic processes (landslides, debrisflow/mudflows, avalanches, riverbed erosions etc) as well as a the rapid growth of the human population (1 172 700) not excluding its functioning as the capital city have all acted as factors in placing Tbilisi into the category of highly dangerous territories, as any natural catastrophe that may occur within the limits of the city will result in excessive economic and humanitarian losses.

Hundreds of settlements, agricultural lands, roads, oil and gas pipelines' routes, towers of high voltage transmission lines, mountain resorts, etc. are periodically experiencing strong influence of landslide-gravitational and debris flow/mudflow processes [4]. Catastrophic events are triggered by earthquakes, extreme hydrometeorological events, large-scale human impacts on the environment and society's low preparedness [5].

Both the population and infrastructure of Tbilisi are territorially situated in dangerous zones in terms of both natural hazards and geo-ecological complications. Such

complications arose as the result of high levels of engineering in geological areas vulnerable to geo-ecological transformations. The city is currently expanding on the account of the area, which has traditionally been considered unsuitable for constructions in terms of engineering geology. Such territories include geologically unstable and highly skewed slopes, gorges filled up with waste and technogenic soil, salty swamps and areas under threat of constant landslides and mudslides. Such activity ultimately led to the development of dangerous geological occurrences (landslides, mudslides, rapid flooding, constant flooding,) on a larger scale, causing a major crisis in geo-ecological terms (figure 2-3). As a result, the rhythm of the city life in Tbilisi is constantly interrupted; transportation routes come under threat, hundreds of constructions including dwellings experience deformation and even complete destruction, often causing human casualties [6; 7].



Figure 2. Landslide in Gldani (Tbilisi).



Figure 3. Debrisflow in Ortachala (Tbilisi).

According to a study conducted by the Geology department of Georgia in there were 200 areas under the danger of landslides, 52 gorges under danger the of transformations due to debrisflow/mudflow and an area under the risk of gravitational rockslides of 20 km of length.

Currently natural hazards have become far more frequent, affecting a wider territory than ever before, as landslides have increased by over 70%. Such developments are closely tied to the fact that there has also been an increase in technogenic activity. The affected territory has exceeded hundreds of acres. A good example of such processes would be the Mukhatgverdi graveyard where the northern region, as well as the transportation roots leading there, have completely come under danger of active and dynamic landslides [6].

One of the example is Tbilisi disaster in the year of 2015. During 13-14 June 2015 heavy rainfall in the Riv. Vere basin area and its tributaries caused a drastic increase in the water level and triggered/activated large-scale landslide, debrisflow, rock avalanche and flood events. This put the Tskneti-Samadlo and Tsnketi-Akhaldaba motorways out of order (figure 4-5). Residential buildings and miscellaneous infrastructural facilities, buildings and structures and Tbilisi Zoo located at the low elevations in the Riv. Vere Gorge were significantly damaged or/and totally destroyed. 23 persons died during the disaster [1].



Figure 4. Akhaldaba "big" Landslide (Tbilisi).



Figure 5. Riv. Vere right bank erosion (Tbilisi).

It is necessary to assess the geo-dynamic situation of

Tbilisi caused by technogenic activity as well as earthquakes. It is also necessary to analyze the transformations in the landscapes in terms of geo-ecology of urbanised areas. Permanent geo-monitoring studies need to be conducted. Landslide susceptibility maps are of great importance to planners and engineers for choosing suitable locations to implement eco-social developments [8].

6. Terrain Transformation

The fact that terrain transformation is most apparent in Tbilisi is clearly demonstrated by the map/photo below. The process has been actively progressing step by step for centuries. One of the reasons for this is the difficult composition of the original terrain, the layers of which had low physical-mechanical features. This further constrained the development of Tbilisi. There are several terrain transformation models. In the process of 3D terrain model construction, the prime task is to modify the discontinuous portion or a partial area of the model, to obtain a more sophisticated and complicated modeling result [9].

One of the main reasons for deformations of constructions in Tbilisi is the technogenic undergroud waterways. The levels of such rivers rise, negatively affecting the most vulnerable 'liosian' as well as clay-like layers. In terms of their geological and engineering qualities. The lower tiers of Tbilisi are flooded in several areas: Krtsanisi, Samgori, Isani, Nadzaladevi, Gldani, Saburtalo and Didi Dighomi. Such flooding processes and the flooding of nearby residential areas as well as the rise of underground water levels are the result of rising water levels in Samgori irrigation systems and the construction of the protective riverbank wall along the river Mtkvari. This was caused by the limitation of normal distribution of surface water coming down from nearby valleys and higher grounds. Another contributing reason was the rise of water levels in the Ortachala Hydro-electric dam waterway systems. The 2012 earthquake that took place on the 25th of April also increased the risks of exo-genic processes, leading to a critical level of landslide risks in areas of high vulnerability due to gravitational activity. A similar situation can be observed in areas of weak layers of ground. The regime of underground waterways was altered as well as their directions. This resulted in higher activity of landslides. Dry gorges were filled with hazardous solid materials heightening the risks of mudslides. A large number of residential areas have therefore become hazardous. [10]

The sustainability of the natural environment as well as protection of civilian lives from hazardous processes is a pivotal issue considering the current socio-economic and ecological state of affairs in Tbilisi. This problem can only be solved with a thorough examination of geo-ecological situation and fully functioning system of geo-monitoring of the city, as according to the research analysis in most cases of large-scale and small-scale geo-ecological problems are caused by improper examinations (figure 6).



Figure 6. Transformed areas (formal agricultural lands according to CORONA 1971).

7. Conclusion

A complex physical-geographical study of Tbilisi allows us to reach a conclusion. During the current socio-economic and ecological crisis it is of utmost importance to sustain a healthy natural ecosystem as well as to protect civilian lives from dangerous processes. This problem can only be solved with a thorough examination of the geo-ecological situation of the city as well as through fully functioning geo-monitoring of the lithosphere, as according to the research analysis in most cases of large-scale and small-scale geo-ecological problems are caused by improper examinations. It is also worth noting that around 60% of older residential constructions of Tbilisi are considered dangerous. Therefore, any further inconsistent constructions would damage the already dwindling ecosystem of Tbilisi.

- Tbilisi needs to be split into zones according to the level of hazardous activity, laying grounds for the creation of the general plan for the city.
- The current state of landscape transformation of Tbilisi must be assessed regularly. A permanent monitoring should be established, giving recommendations to those concerned. The separation of different zones of Tbilisi should consider economic and ecological factors, with the city split into zones according to ecological hazards, vulnerability of landscape, etc.

During the centuries of Tbilisi's existence the flora of the surrounding areas of the city was destroyed by human activity, which had negative effects on the landscape.

Mountain-sides began to be eroded intensively, resulting in deforestation and the creation of cliff-sides and unstable gorges. Thus, heavy rainfall often results in mudslides and landslides, due to the easily breakable clay-like top layers of landscape. It is evident that most of these factors are a result of anthropogenic activity. All the above mentioned man-made factions (and more) must be taken into account when undertaking any form of scientific research or other human activity like agriculture or constructions. Every specific feature of the landscape must be considered in order to properly conduct any activity, using all possibilities offered by the terrain and preserving the natural balance of the environment. The ever-increasing demand of real-estate and constructions has led to the absorption of problematic terrain into the city in terms of geo-ecology. This results in the reactivation and hazardous exo-dynamic processes and further deterioration of geo-ecology. Note-worthy factors: - landslide processes; - Debrisflow/Mudflows result of heavy rainfall; - Rockfall/Rock avalanches; - inundation result of groundwater level increase; - Flooding.

It is widely believed that the changing climate conditions on earth are a result of the activation of geo-dynamic processes on the global scale. It is probable that Georgia, being in a highly hazardous region in terms of exo-dynamic processes, tectonic shifts, climate and topography, will suffer to a great degree, when the predicted extreme weather conditions will reach a critical level.

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